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NUTRITIONAL STATUS, EXERCISE, AND INSULIN SENSITIVITY

A thesis presented in partial fulfilment of the requirements for
the degree of Doctor of Philosophy in Public Health.

Massey University, Manawatu,
New Zealand.

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Abstract

The insulin-glucose system in lean-healthy people adapts its normal function in the face of challenging metabolic conditions. To improve understanding of these adaptations, I exposed subjects to periods of starvation, high-protein-low-carbohydrate diet (HPLC) and overfeeding.

In six lean-healthy men, dietary carbohydrate was eliminated but gluconeogenic substrate supply was maintained by three-day HPLC diet, compared with three-day starvation and three-day mixed-carbohydrate diet. Insulin sensitivity, vastus lateralis intramyocellular lipid (IMCL) and fasting glucose were unaffected by HPLC diet, although they were significantly altered after starvation. These results indicate that dietary carbohydrate restriction does not trigger metabolic adaptations, although total metabolic carbohydrate supply remains likely to be important.

Six lean-healthy men underwent two three-day periods of starvation with either no exercise or daily endurance exercise (80 min.day$^{-1}$ at 50% VO$_{2\text{Max}}$) and a three-day mixed diet without exercise. Compared to mixed diet, starvation elevated fasting FFA and IMCL and decreased insulin sensitivity and fasting glucose. Exercise during starvation prevented the elevation of IMCL but did not prevent other metabolic disruption, in contrast with exercise during lipid infusion.

Maintaining high physical-activity may prevent the metabolic disruption associated with overfeeding, while insulin sensitivity may predict partitioning of fuel between tissues during overfeeding. Nine endurance-trained athletes maintained their normal physical-
activity while consuming a diet providing 90 kJ.(kg body mass)$^{-1}$.day$^{-1}$ above their normal dietary intake for four weeks. Subjects’ body-mass, fat-mass and body fat% increased while insulin sensitivity tended to decrease (14.5 ± 5.9 to 9.5 ± 4.1 min$^{-1}$.mU.l$^{-1}$, p = 0.08). Change in insulin sensitivity was correlated with change in body fat % (r = -0.77, p < 0.023). Initial insulin sensitivity was correlated with change in body fat% (r = 0.90, p < 0.009) and the proportion of mass gained as lean tissue (r = 0.86, p < 0.024).

Maintenance of already high physical-activity cannot prevent metabolic disruption associated with overfeeding. These results also suggest that insulin sensitivity influences energy partitioning between tissues.

The results in this thesis suggest important interaction effects between exercise and diet. I propose that carbohydrate availability is a key modulator of the effects of exercise on metabolism in lean-healthy men.
The completion of this thesis would not have been possible without the generous assistance of many people. First and foremost I would like to thank my wife, Rose, for providing loving support and a sympathetic ear. I am also particularly indebted to my primary supervisor, Dr Stephen Stannard, who guided me away from many scientific pitfalls and made available whatever resources were needed. My co-supervisor Dr Chris Cunningham provided sage advice on the doctoral study process and co-supervisors Dr Nathan Johnson and Dr Peter Snell who provided physiological advice. I have enjoyed the collegial support of my fellow post-graduate students: Jon Hughes, Matt Barnes, Zac Schlader, Bob Stewart, Rachel Mason and Aaron Raman; and of Massey University staff Dr Jane Coad and Dr Toby Mundel. None of my research would have been possible without the technical assistance that was provided by Matt Barnes, Dr Pat Ruell, Dr Toos Sachinwalla, Chris Booth and Dr David Simcock. Perhaps most importantly, I am grateful to the subjects who endured unusually unpleasant interventions with stoic determination.

All the experiments presented in this thesis were approved by the local human ethics committee at the institution where they were performed, and complied with the Declaration of Helsinki.
# Table of Contents

Abstract ................................................................................................................. i  
Acknowledgements ............................................................................................... iii 
Table of Contents ................................................................................................... iv 
List of Figures ......................................................................................................... x 
List of Tables .......................................................................................................... xii 
List of Equations .................................................................................................... xv 
1 Background .......................................................................................................... 1  
2 Issues associated with human research ............................................................ 3  
3 Introduction: Energy substrates, exercise and insulin sensitivity .................. 6  
4 Literature Review ................................................................................................. 10  
5 Hypotheses ........................................................................................................... 59  
6 Research Design .................................................................................................. 60  
7 Review of techniques ........................................................................................... 61  
8 Low-carbohydrate diet does not affect insulin sensitivity when protein intake is elevated ......................................................................................................................... 120  
9 Moderate intensity endurance exercise prevents short term starvation induced intramyocellular lipid accumulation but not insulin resistance .................. 143  
10 Continued endurance training cannot prevent decreased insulin sensitivity associated with overfeeding ......................................................................................................................... 164  
11 Comparison of indices of insulin sensitivity .................................................... 193  
12 Conclusions and future directions ..................................................................... 195  
13 Glossary ............................................................................................................... 205  
14 Appendices ......................................................................................................... 209  
15 Bibliography ....................................................................................................... 274
**Table of Contents**

**Extended Table of Contents**

Abstract ............................................................................................................................................ i

Acknowledgements ........................................................................................................................ iii

Table of Contents .............................................................................................................................. iv

List of Figures ..................................................................................................................................... x

List of Tables ..................................................................................................................................... xii

List of Equations .............................................................................................................................. xv

1 **Background** ............................................................................................................................. 1

2 **Issues associated with human research** ................................................................................. 3

3 **Introduction: Energy substrates, exercise and insulin sensitivity** ......................................... 6

4 **Literature Review** ................................................................................................................... 10

   4.1 **Introduction** ..................................................................................................................... 10

   4.2 **The insulin-glucose system** ............................................................................................. 11

       4.2.1 Requirement to maintain blood glucose concentration ........................................... 11

       4.2.2 Hormonal regulation of blood glucose ........................................................................ 12

       4.2.3 Insulin signalling of glucose uptake in skeletal muscle ............................................. 14

   4.3 **Acute dietary interventions and insulin sensitivity** ......................................................... 17

       4.3.1 Starvation .................................................................................................................... 17

       4.3.2 Carbohydrate deprivation ............................................................................................ 35

       4.3.3 Lipid oversupply ........................................................................................................... 36

   4.4 **Exercise and insulin sensitivity** ....................................................................................... 38

       4.4.1 Acute metabolic effect of exercise .............................................................................. 38
Table of Contents

4.4.2 Chronic metabolic effect of exercise .......................................................... 41
4.4.3 Intramyocellular FFA balance during exercise ............................................. 44
4.4.4 Exercise during starvation ........................................................................ 46
4.4.5 Summary of exercise and insulin sensitivity ................................................. 48
4.5 Overfeeding, body composition and insulin sensitivity .................................... 49
  4.5.1 Mechanisms of decreased insulin sensitivity during obesity ...................... 49
  4.5.2 Experimental overfeeding and insulin sensitivity ........................................ 54
  4.5.3 Experimental overfeeding causes variable weight gain .............................. 55
  4.5.4 Summary of overfeeding .......................................................................... 58
5 Hypotheses ...................................................................................................... 59
6 Research Design ............................................................................................. 60
7 Review of techniques ...................................................................................... 61
  7.1 To determine insulin sensitivity ..................................................................... 61
    7.1.1 Direct Measures of Insulin Sensitivity ..................................................... 61
    7.1.2 Frequently Sampled Intravenous Glucose Tolerance Tests ...................... 69
    7.1.3 Oral Glucose Tolerance Tests ................................................................... 77
    7.1.4 Fasting Measurements ............................................................................ 81
  7.2 To determine intramyocellular lipid concentration ......................................... 87
  7.3 To determine free living energy expenditure ................................................ 95
  7.4 To determine free living energy intake ....................................................... 108
  7.5 To determine body composition ................................................................... 114
8 Low-carbohydrate diet does not affect insulin sensitivity when protein intake is
  elevated ............................................................................................................. 120
  8.1 Introduction .................................................................................................. 120
Table of Contents

8.2 Materials and Methods ................................................................. 123

8.2.1 Subjects .................................................................................. 123
8.2.2 Preliminary testing ................................................................. 123
8.2.3 Experimental protocol .......................................................... 125
8.2.4 Determination of intramyocellular lipid content ......................... 127
8.2.5 Intravenous glucose tolerance test .......................................... 128
8.2.6 Blood sampling ..................................................................... 129
8.2.7 Analytical procedures and calculations .................................... 129
8.2.8 Analysis .................................................................................. 130

8.3 Results ......................................................................................... 131

8.3.1 Subject characteristics .......................................................... 131
8.3.2 Dietary intake ........................................................................ 131
8.3.3 Intramyocellular lipid content ............................................... 131
8.3.4 Basal plasma metabolite and insulin concentrations .................. 132
8.3.5 Plasma metabolite and insulin responses to IVGTT .................... 134
8.3.6 Minimal model analysis ......................................................... 137
8.3.7 Glucose tolerance ................................................................. 137

8.4 Discussion .................................................................................. 138

9 Moderate intensity endurance exercise prevents short term starvation induced intramyocellular lipid accumulation but not insulin resistance .............. 143

9.1 Introduction ................................................................................. 143

9.2 Materials and Methods ............................................................. 146

9.2.1 Subjects .................................................................................. 146
9.2.2 Preliminary testing ................................................................. 146
9.2.3 Experimental protocol .......................................................... 148
# Table of Contents

9.2.4 Determination of intramyocellular lipid content ........................................ 150
9.2.5 Intravenous glucose tolerance test .......................................................... 151
9.2.6 Blood sampling ......................................................................................... 152
9.2.7 Analytical procedures and calculations .................................................... 152
9.2.8 Analysis ....................................................................................................... 153

9.3 Results ........................................................................................................... 154

9.3.1 Subject characteristics ................................................................................ 154
9.3.2 Diet and exercise ....................................................................................... 154
9.3.3 Intramyocellular lipid content ..................................................................... 154
9.3.4 Basal plasma metabolite and insulin concentrations .............................. 156
9.3.5 Plasma metabolite and insulin responses to IVGTT ................................. 156
9.3.6 Minimal model analysis ............................................................................. 158

9.4 Discussion ....................................................................................................... 159

10 Continued endurance training cannot prevent decreased insulin sensitivity

associated with overfeeding .............................................................................. 164

10.1 Introduction ................................................................................................... 164

10.2 Materials and Methods ................................................................................ 167

Subjects .............................................................................................................. 167
Protocol ............................................................................................................... 167
Subject characterisation ..................................................................................... 168
Establishing baseline ......................................................................................... 169
Pre-testing .......................................................................................................... 169
Overfeeding intervention .................................................................................... 170
Post-testing ......................................................................................................... 171
Analytical procedures and calculations ............................................................ 171
# Table of Contents

Statistical analyses ........................................................................................................ 172

10.3 Results .................................................................................................................... 174

10.4 Discussion ................................................................................................................ 183

11 Comparison of indices of insulin sensitivity ................................................................. 193

12 Conclusions and future directions .............................................................................. 195

13 Glossary ....................................................................................................................... 205

14 Appendices .................................................................................................................. 209

14.1 Calculation of unbound FFA concentration from total plasma FFA ..................... 209

14.2 Raw and false discovery rate corrected P values for comparisons made in the
overfeeding study .............................................................................................................. 211

14.3 Skewness and kurtosis of variables used in correlation analyses ...................... 213

14.4 Raw data from high protein diet study ................................................................. 214

14.5 Raw data from exercise during starvation study .................................................. 227

14.6 Raw data from overfeeding study ......................................................................... 239

14.7 Peer-reviewed article: Low-carbohydrate diet does not affect intramyocellular
lipid concentration or insulin sensitivity in lean, physically fit men when protein intake
is elevated ......................................................................................................................... 253

14.8 Peer-reviewed article: Moderate-intensity endurance exercise prevents short term
starvation-induced intramyocellular lipid accumulation but not insulin resistance..... 265

15 Bibliography ............................................................................................................... 274
List of Figures

Figure 4-1. Insulin signalling of GLUT4 translocation and glycogen synthesis. .............. 16
Figure 4-2. Potential regulation of insulin signalling by intracellular FFA and FFA by products......................................................................................................................... 34
Figure 7-1. Glucose response to different levels of insulin infusion during a euglycaemic clamp........................................................................................................................................ 65
Figure 7-2. Schematic diagram of the minimal model of glucose disposal............... 71
Figure 8-1. Effect of 67 h of mixed diet, high-protein/low-carbohydrate (HPLC) diet or starvation on intramyocellular lipid (IMCL):water ratio......................................................... 133
Figure 8-2. Effect of 67 h of mixed diet, high-protein/low-carbohydrate (HPLC) diet or starvation on plasma glucose, insulin and free fatty acid concentrations during an intravenous glucose tolerance test. ........................................ 136
Figure 9-1. Effect of 67 h of inactivity + mixed diet, inactivity + starvation or exercise + starvation on (A) plasma glucose, (B) insulin and (C) free fatty acid concentrations during an intravenous glucose tolerance test............................................................ 157
Figure 10-1. Schematic of overfeeding study protocol............................................... 168
Figure 10-2. Change in body mass during overfeeding and washout......................... 176
Figure 10-3. Plasma glucose, insulin and free fatty acid (FFA) response to the intravenous glucose tolerance test before and after overfeeding................................. 178
Figure 10-4. Relationship between change in insulin sensitivity ($S_i$) and change in body fat during overfeeding.............................................................. 180
Figure 10-5. Relationship between initial insulin sensitivity ($S_i$) and change in body fat during overfeeding................................................................. 181
List of Figures

Figure 10-6. Relationship between daily energy expenditure relative to lean tissue mass and change in body fat during overfeeding. ................................................................. 182

Figure 10-7. Potential negative feedback system involving fat gain and insulin sensitivity. .................................................................................................................. 191

Figure 11-1 Relationships between fasting indices of insulin sensitivity and insulin sensitivity determined from FSIVGTT (Si). Pearson correlations were r=-0.39, 0.28, and 0.36 for QUICKI, HOMA IR, and log(HOMA) respectively, n=42. .......................... 193
List of Tables

Table 4-2: Summary of research linking intracellular FFA or its metabolites to decreased insulin sensitivity in whole organisms or skeletal muscle tissue. ........................................ 25
Table 8-1 Forty-eight hour dietary analysis of group daily macronutrient intake. .......... 132
Table 8-2 Basal plasma substrate and insulin concentrations after dietary interventions. ........................................................................................................ 133
Table 9-1. Basal substrate and insulin concentrations and intravenous glucose tolerance test results after 67 hours of dietary intervention................................................ 155
Table 10-1. Body composition and plasma metabolite concentrations measured after an overnight fast before and after overfeeding ............................................. 175
Table 12-1: Summary of human research describing the effect of dietary interventions and exercise on whole body insulin sensitivity ........................................... 198
Table 14-1 Subject characteristics ........................................................................ 214
Table 14-2 Dietary intake during mixed diet .............................................................. 214
Table 14-3 Dietary intake during high protein, low carbohydrate diet ...................... 215
Table 14-4 Magnetic resonance spectroscopy (IMCL amplitude)/(water amplitude) after each dietary intervention. Dimensionless units ........................................ 215
Table 14-5 Fasting plasma FFA concentration after each intervention (mM) ............. 216
Table 14-6 Fasting plasma glucose concentration after each intervention (mM) ........... 216
Table 14-7 Fasting plasma insulin concentration after each intervention (pM) .......... 217
Table 14-8 Minimal model insulin sensitivity after each intervention (l.min⁻¹.µU⁻¹) .... 217
Table 14-9 Minimal model glucose effectiveness after each intervention (min⁻¹) ...... 218
Table 14-10 Kg (insulin response to the IVGTT) after each intervention (mmol.l⁻¹.min⁻¹) ..................................................................................................................... 218
List of Tables

Table 14-11 Glucose AUC after each intervention (mmol.l$^{-1}$.min$^{-1}$) ........................................ 219
Table 14-12 Insulin AUC after each intervention (pmol.l$^{-1}$.min$^{-1}$) ........................................ 219
Table 14-13 Plasma glucose and insulin concentrations throughout the IVGTT .......................... 220
Table 14-14 Plasma FFA concentrations throughout the IVGTT .................................................. 225
Table 14-15 Subject characteristics .................................................................................................. 227
Table 14-16 Dietary intake during mixed diet ................................................................................... 227
Table 14-17 IMCL amplitude/water amplitude after each dietary intervention.  
Dimensionless units .......................................................................................................................... 228
Table 14-18 Fasting plasma FFA concentration after each intervention (mM) .............................. 228
Table 14-19 Fasting plasma glucose concentration after each intervention (mM) ....................... 229
Table 14-20 Fasting plasma insulin concentration after each intervention (pM) ......................... 229
Table 14-21 Minimal model insulin sensitivity after each intervention (l.min$^{-1}$.µU$^{-1}$) ...... 230
Table 14-22 Minimal model glucose effectiveness after each intervention (min$^{-1}$) .............. 230
Table 14-23 Glucose AUC after each intervention (mmol.l$^{-1}$.min$^{-1}$) ..................................... 231
Table 14-24 Insulin AUC after each intervention (pmol.l$^{-1}$.min$^{-1}$) ....................................... 231
Table 14-25 Plasma glucose and insulin concentrations throughout the IVGTT .................... 232
Table 14-26 Plasma FFA concentrations throughout the IVGTT ................................................. 237
Table 14-27 Subject characteristics .................................................................................................. 239
Table 14-28 Diet and energy expenditure ......................................................................................... 240
Table 14-29 Body composition and body mass before and after overfeeding ............................. 241
Table 14-30 Fasting blood metabolites before and after overfeeding ....................................... 242
Table 14-31 Minimal model and AUC data from the IVGTT before and after overfeeding  ....... 243
Table 14-32 Plasma glucose and insulin concentrations during the IVGTT before and after overfeeding ........................................................................................................................................ 244
List of Tables

Table 14-33 Plasma FFA concentrations throughout the IVGTT before and after overfeeding .......................................................... 251
# List of Equations

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equation 7-2</td>
<td>( \frac{dx}{dt} = -p_2X(t) + p_3[I(t) - I_b] )</td>
</tr>
<tr>
<td>Equation 7-4</td>
<td>[ \text{HOMA}_R = \frac{(I_0 X G_0)}{22.5} ]</td>
</tr>
<tr>
<td>Equation 7-5</td>
<td>[ \text{QUICKI} = \frac{1}{\log(I_0 X G_0)} ]</td>
</tr>
<tr>
<td>Equation 7-6</td>
<td>( \text{H}_2\text{O} + \text{CO}_2 \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{HCO}_3^- + \text{H}^+ ) (Lifson, Gordon et al. 1949)</td>
</tr>
<tr>
<td>Equation 7-7</td>
<td>( T_{\text{CO}<em>2} = \frac{N(f</em>{18O} - f_{2H})}{2} ) (Lifson, Gordon et al. 1955)</td>
</tr>
<tr>
<td>Equation 7-8</td>
<td>( T_{\text{EE}} = 14.61T_{\text{O}<em>2} + 4.63T</em>{\text{CO}_2} - 9.08T_N ) (Weir 1949)</td>
</tr>
<tr>
<td>Equation 7-9</td>
<td>( V_{\text{Lats}} = \frac{[V_{\text{Bag}} (%N_2 - %\text{Impure})]}{[80 - (%N_2 + 0.2)]} - \text{DS} )</td>
</tr>
<tr>
<td>Equation 7-10</td>
<td>( BD = \text{(weight in air)} \times \text{(density of water)} / \text{(weight in water)} )</td>
</tr>
<tr>
<td>Equation 7-11</td>
<td>( %BF = \frac{497.1}{BD} - 451.9 )</td>
</tr>
<tr>
<td>Equation 8-1</td>
<td>( %BF = \frac{497.1}{BD} - 451.9 ) (Brozek, Grande et al. 1963)</td>
</tr>
<tr>
<td>Equation 8-2</td>
<td>( V_{\text{Lats}} = \frac{[V_{\text{Bag}} (%N_2 - %\text{Impure})]}{[80 - (%N_2 + 0.2)]} - \text{DS} )</td>
</tr>
<tr>
<td>Equation 9-2</td>
<td>( V_{\text{Lats}} = \frac{[V_{\text{Bag}} (%N_2 - %\text{Impure})]}{[80 - (%N_2 + 0.2)]} - \text{DS} )</td>
</tr>
<tr>
<td>Equation 14-1</td>
<td>( [\text{FFA}] = \frac{(K_d.v)}{(n-v)} ) (Bojesen and Bojesen 1992)</td>
</tr>
</tbody>
</table>